

TITLE OF THE INVENTION

**BIT-RATE INDEPENDENT OPTICAL RECEIVER AND METHOD
THEREOF**

CLAIM OF PRIORITY

This application makes reference to, incorporates the same herein, and claims all benefits accruing under 35 U.S.C. § 119 from an application for *AN OPTICAL RECEIVERS WITH BIT-RATE INDEPENDENT CLOCK AND DATA RECOVERY AND METHOD THEREFOR* earlier filed in the Korean Industrial Property Office on the 5th of August 1999 and there duly assigned Serial No. 32170/1999.

BACKGROUND OF THE INVENTION

Technical Field

The present invention relates generally to an optical receiver for converting an input optical signal to an electrical signal for data recovery and a method thereof in an optical transmission system.

Related Art

A variety of protocols are available to an optical transmission system, such as protocols for fiber distributed data interface (FDDI), enterprise systems connectivity (ESCON), fiber channel, gigabit Ethernet, and asynchronous transfer mode (ATM). Various bit rates are used for the protocols, including 125 megabits per second (Mbps), 155 Mbps, 200 Mbps, 622 Mbps, 1062 Mbps, 1.25 gigabits per second (Gbps), and 2.5 Gbps.

Among the protocols and bit rates, an optical transmission system selects an appropriate protocol/bit rate. Since the bit rate of an optical signal is preset in the optical transmission system, an optical receiver in a relay or a terminal operates at the bit rate according to the selected protocol. The bit rate corresponds to a transmission rate. The bit rate can be expressed as a transmission rate of a number of bits per second (bps).

I have found that it would be desirable to improve optical receiver technology. Efforts have been made to improve optics-related technologies.

Exemplars of recent efforts in the art include U.S. Serial No. 09/484,061 for *METHOD AND APPARATUS FOR IDENTIFYING BIT RATE* applied for by Yang, U.S. Patent No. 5,181,134 for *A Photonic Cross-Connect Switch* issued to Fatehi et al., U.S. Patent No. 4,888,791 for *A Clock Decoder and Data Bit Transition Detector for Fiber Optic Work Station* issued to Barndt, Sr., U.S.

1 Patent No. 5,510,919 for *An Optical System for Transmitting a Multilevel Signal* issued to Wedding,
2 U.S. Patent No. 5,144,469 for *A Method for the Transmission of Data Between Two Stations by*
3 *Means of Optical Waveguides* issued to Brahms et al., U.S. Patent No. 5,550,864 for *A Bit Rate-*
4 *Insensitive Mechanism for Transmitting Integrated Clock and Data Signals over Digital*
5 *Communication Link* issued to Toy et al., U.S. Patent No. 4,524,462 for *A System for Jointly*
6 *Transmitting High-Frequency and Low-Frequency Digital Signals over a Fiber-Optical Carrier*
7 issued to Cottatelucci, U.S. Patent No. 6,069,722 for *A Transmitter for Optically Transmitting*
8 *Analog Electric Signals, and Digital Transmission System* issued to Schlag, U.S. Patent No.
9 6,034,801 for *A Transmitting Device, Transmitting Apparatus and Optical Transmission System for*
10 *Optically Transmitting Analog Electrical Signals* issued to Pfeiffer, and U.S. Patent No. 4,475,212
11 for *A Frequency-Independent, Self-Clocking Encoding Technique and Apparatus for Digital*
12 *Communications* issued to McLean et al..

13 While these recent efforts provide advantages, I note that they fail to adequately provide an
14 improved bit-rate independent optical receiver and method thereof having enhanced efficiency.

15 SUMMARY OF THE INVENTION

16 It is, therefore, an object of the present invention to provide a bit-rate independent optical
17 receiver for accommodating optical signals at different bit rates and a method thereof.

18 It is another object of the present invention to provide a bit-rate independent optical receiver

1 for recovering data and clock signals from optical signals received at different bit rates, and a method
2 thereof.

3 It is a further object of the present invention to provide a bit-rate independent optical receiver
4 and a method thereof, which can increase transmission quality and a transmission distance.

5 These and other objects can be achieved by providing a bit-rate independent optical receiver.
6 In the bit-rate independent optical receiver, an optoelectric converter converts an input optical signal
7 to an original electrical signal, a bit rate identifying unit performs an exclusive-OR (XOR) logic
8 operation upon the original electrical signal received from the optoelectric converter and a second
9 signal corresponding to the original electrical signal delayed by a predetermined time, and detects
10 a bit rate from the resultant signal resulting from the exclusive-OR logic operation, a reference clock
11 generator generates a reference clock signal according to the detected bit rate, and a clock and data
12 recovery circuit recovers a clock signal and data from the input signal according to the reference
13 clock signal.

14 To achieve these and other objects in accordance with the principles of the present invention,
15 as embodied and broadly described, the present invention provides a bit-rate independent optical
16 receiver comprising: an optoelectric converter for converting an input optical signal to an electrical
17 signal; a bit rate identifying unit having a identification signal generator for delaying the input signal,

1 comparing the delayed signal with the original input signal period by period, and generating a
2 sensing signal, and a bit rate deriving unit for loss-pass-filtering the sensing signal and determining
3 the bit rate from the resulting voltage level; a reference clock generator having a plurality of
4 oscillators for generating clock signals of different frequencies, for selectively operating the
5 oscillators to generate the reference clock signal the same as the bit rate detected by the bit rate
6 identifying unit; and a clock and data recovery circuit for recovering a clock signal and data from
7 the input signal according to the reference clock signal.

To achieve these and other objects in accordance with the principles of the present invention,
as embodied and broadly described, the present invention provides an apparatus, comprising: a
converter converting an input optical signal to an original electrical signal; an identification unit
receiving said original electrical signal, generating a first signal corresponding to said original
electrical signal delayed by a predetermined quantity of time, generating a second signal corresponding
to said original electrical signal not delayed, comparing said first and second signals, forming a third
signal in dependence upon said comparing of said first and second signals, detecting a bit rate in
dependence upon said third signal; a clock generator generating a reference clock signal in
dependence upon said detected bit rate; and a recovery unit recovering an input clock signal and data
from said input optical signal in dependence upon said reference clock signal.

To achieve these and other objects in accordance with the principles of the present invention,

1 as embodied and broadly described, the present invention provides a method of operating a receiver
2 which functions independently of a bit rate of a received signal, comprising: receiving an original
3 signal; generating a resultant signal by comparing a first signal and a second signal, said first signal
4 corresponding to said original signal delayed by a predetermined quantity of time, said second signal
5 corresponding to said original signal not delayed; determining a bit rate of said original signal in
6 dependence upon said resultant signal; generating a reference clock signal in dependence upon said
7 determined bit rate; and recovering an input clock signal and data from said original signal in
8 dependence upon said reference clock signal.

9 To achieve these and other objects in accordance with the principles of the present invention,
10 as embodied and broadly described, the present invention provides an apparatus, comprising: a
11 converter converting an input optical signal to an original electrical signal; an identification unit
12 receiving said original electrical signal, generating a first signal corresponding to said original
13 electrical signal delayed by a pretermined quantity of time, generating a second signal corresponding
14 to said original electrical signal not delayed, forming a third signal by performing an exclusive-OR
15 logic operation upon said first and second signals, detecting a bit rate in dependence upon said third
16 signal; a clock generator generating a reference clock signal in dependence upon said detected bit
17 rate; and a recovery unit recovering an input clock signal and data from said input optical signal in
18 dependence upon said reference clock signal.

1 The present invention is more specifically described in the following paragraphs by reference
2 to the drawings attached only by way of example. Other advantages and features will become
3 apparent from the following description and from the claims.

4 BRIEF DESCRIPTION OF THE DRAWINGS

5 In the accompanying drawings, which are incorporated in and constitute a part of this
6 specification, embodiments of the invention are illustrated, which, together with a general
7 description of the invention given above, and the detailed description given below, serve to
exemplify the principles of this invention.

FIG. 1 is a schematic block diagram of an optical receiver;

FIG. 2 is a block diagram of an optical receiver according to an embodiment of the present
invention, in accordance with the principles of the present invention;

FIG. 3 is a block diagram of a bit rate identifying unit shown in FIG. 2, in accordance with
the principles of the present invention;

FIGS. 4A and 4B are exemplary waveforms output from function blocks, for describing the
operation of the bit rate identifying unit shown in FIG. 3, in accordance with the principles of the
present invention; and

FIG. 5 is graph showing the relationship between the bit rate of an optical signal versus the
output direct current (DC) level of a filter shown in FIG. 3, in accordance with the principles of the
present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

While the present invention will be described more fully hereinafter with reference to the accompanying drawings, in which a preferred embodiment of the present invention is shown, it is to be understood at the outset of the description which follows that persons of skill in the appropriate arts may modify the invention here described while still achieving the favorable results of this invention. Accordingly, the description which follows is to be understood as being a broad, teaching disclosure directed to persons of skill in the appropriate arts, and not as limiting upon the present invention.

FIG. 1 is a schematic block diagram of an optical receiver. Referring to FIG. 1, the optical receiver is comprised of an optoelectric (O/E) converter 10, an amplifier (AMP) 20 for amplifying an electrical signal outputted from the optoelectric converter 10, a clock generator 40 for generating a reference clock signal according to the bit rate of an input optical signal, and a clock and data recovery (CDR) circuit 30 for recovering a clock signal and data from an amplified signal received from the amplifier 20.

An optical signal is input to the optoelectric converter 10 at a bit rate preset according to a single protocol used in a corresponding optical transmission system. Therefore, the optical receiver receives an optical signal at the single bit rate. The clock and data recovery circuit 30 receives a

1 clock signal of a predetermined single frequency according to the bit rate from the clock generator
2 40 and recovers data and a clock signal from the input signal based on the single reference clock
3 signal by reshaping, regeneration, and retiming.

4 Optical communication systems are being developed from a time division multiplexing
5 (TDM) to a wavelength division multiplexing (WDM). The wavelength division multiplexing
6 scheme multiplexes a plurality of channels at different wavelengths and propagates the multiplexed
7 optical signals onto a single optical fiber. Accordingly, research has been conducted on a
8 multiplexing of optical signals in different channels with different protocols and bit rates into one
9 strand of optical fiber. Due to an increasing demand for optical transmission systems and the
10 increase of data traffic especially in metropolitan areas, a wavelength division multiplexing system
11 for use in metropolitan areas should be flexible enough to accommodate various formats for fiber
12 distributed data interface (FDDI), enterprise systems connectivity (ESCON), fiber channel, gigabit
13 Ethernet, and asynchronous transfer mode (ATM), which mainly deal with data traffic, as well as
14 those for synchronous digital hierarchy/synchronous optical network (SDH/SONET) evolved from
15 voice transmission.

Sub B4 In this context, a so-called protocol free system has been developed to accommodate optical
17 signals at different bit rates. Therefore, optical signals are recovered just by waveform shaping, that
18 is, reshaping and regeneration, without recovering a clock signal. The resulting noise and timing

1 jitters increased as an optical signal passes through nodes decreases transmission quality. In
2 particular, a receiver or transponder confined to the reshaping and regeneration function is limited
3 in transmission distance due to the decreased transmission quality when various protocols/bit rates
4 are used in an optical network.

5 A preferred embodiment of the present invention will be described hereinbelow with
6 reference to the accompanying drawings. In the following description, well-known functions or
7 constructions are not described in detail since they would obscure the invention in unnecessary
detail.

8 An optical receiver according to the present invention receives optical signals at different bit
9 rates from remote optical transmission systems and detects the bit rates of the received optical
10 signals. It also recovers the received signals through retiming using clock signals having the same
11 bit rate with the input data extracted from the received optical signals.

12
13 FIG. 2 is a block diagram of an optical receiver according to an embodiment of the present
14 invention. The optical receiver is a protocol-free one independent of a bit rate and can operate with
15 an optical signal received at any bit rate. The optical receiver operates independently of the input
16 signal's bit rate. The optical receiver is insensitive to bit rate. The optical receiver is transparent to
17 signal bit rate.

Referring to FIG. 2, the optical receiver includes the optoelectric converter 10 for converting an optical signal received at any bit rate to an electrical signal, the amplifier 20 for amplifying the electrical signal outputted from the optoelectric converter 10, a bit rate identifying unit 50 for identifying a bit rate from the received signal, a reference clock generator 60 for generating a reference clock signal according to the identified bit rate, and a clock and data recovery circuit 70 for recovering a clock signal and data from the amplified signal received from the amplifier 20 by means of the reference clock signal generated from the reference clock generator 60.

Since the optical signal inputted to the optoelectric converter 10 is very weak, because the signal reaches the corresponding receiver after being transmitted a long distance, the amplifier 20 is included to amplify this input signal to an appropriate level.

Sub B57 An optical signal is applied at a certain bit rate in a certain protocol to the input of the optoelectric converter 10. The input optical signal is converted to an electrical signal by the optoelectric converter 10 and its bit rate is identified by the bit rate identifying unit 50. The reference clock generator 60 includes a plurality of oscillators for generating clock signals with different frequencies, which is different than the clock generator 40 shown in Fig. 1. The clock generator 40 in Fig. 1 only generates a single type of clock signal, in accordance with the single bit rate of the input optical signal, as shown in Fig. 1. However, the reference clock generator 60 selectively operates the internal oscillators to generate a reference clock signal at a detected bit rate.

1 The clock and data recovery circuit 70 is a programmable circuit, which is different than the clock
2 and data recovery circuit 30 shown in Fig. 1, for reshaping, regeneration, and retiming of an input
3 signal according to the reference clock signal received from the reference clock generator 60.

4 For reference, XOR-gating two particular signals is the equivalent of performing an
5 exclusive-OR logic operation upon those two particular signals. The bit rate identifying unit 50
6 identifies the bit rate of an input signal from a signal delayed from the input signal by a
7 predetermined time and a voltage level produced by XOR-gating the input signal with the delayed
8 signal and then low-pass-filtering the XOR-gated signal. A bit rate identifying unit has been
9 described in U.S. Serial No. 09/484,061 entitled "Method and apparatus for identification of bit rate,"
10 here incorporated by reference. The structure and operation of the bit rate identifying unit 50 will
11 be described in detail referring to the attached drawings.

12 FIG. 3 is a block diagram of the bit rate identifying unit shown in FIG. 2 and FIGs. 4A and
13 4B shows signals outputted from function blocks, for describing the operation of the bit rate
14 identifying unit shown in FIG. 3. Referring to FIGs. 3, 4A, and 4B, the bit rate identifying unit 50
15 includes an identification signal generator 40a for delaying an input signal by a long time period,
16 comparing the original signal with the delayed signal period by period, and generating a sensing
17 signal, and a bit rate deriving unit 40b for determining a bit rate of the received signal from a voltage
18 level obtained by low-pass-filtering the identification signal.

The identification signal generator 40a includes a buffer 41 for duplicating an input signal into two signals equal to the input signal, a delay 42 for delaying one of the buffer outputs by a predetermined time, and an operator 43 for performing the exclusive-OR (XOR) operation upon the delayed signal and the original input signal, and generating a bit rate identification signal.

With reference to Fig. 4A, in the thus-constituted bit rate identification signal generator 40a, the delay 42 generates a signal (b) delayed from an input signal (a) by a predetermined time D, for the input of the signal (a) with pulse period 2T. Here, D is T/2 for example. The operator 43 generates a sensing signal (c) by XOR-gating the input signal (a) with the delayed signal (b). The sensing signal (c) has a plurality of pulses with high level periods presented at the same intervals as D. For example, at a first moment in time, if original input signal (a) corresponds to a 0 and delayed signal (b) also corresponds to a 0, then the resulting sensing signal (c) will be a 0 due to the logical exclusive-OR gate operation performed upon signals (a) and (b). At a second moment in time, if signal (a) is a 0 and signal (b) is a 1, then the signal (c) will be a 1 due to the logical exclusive-OR gate operation. At a third moment in time, if signal (a) is a 1 and signal (b) is a 0, then signal (c) will be a 1. At a fourth moment in time, if signal (a) is a 1 and signal (b) is also a 1, then signal (c) will be a 0.

Meanwhile, FIG. 4B illustrates an input signal (a) at a different bit rate from that of the input signal (a) shown in FIG. 4A. In FIG. 4B, the bit rate of the input signal (a) is a fourth of that of the

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1 input signal (a) shown in FIG. 4A, that is, the input signal (a) has pulse period T four times greater
2 than T. The delay 42 generates a signal (b) delayed from the input signal (a) by $D = T/2$, namely,
3 $T/8$. The operator 43 EXOR-gates the input signal (a) with the delayed signal (b) and generates
4 a sensing signal (c). The sensing signal (c) has a plurality of pulses with high level periods
5 presented at the same intervals as D.

6 In comparison between FIGs. 4A and 4B, when the sensing signals are generated using input
7 signals received for the same time period, the pulses of the sensing signal (c) are a few times more
than those of the sensing signal (c). That is, the pulse numbers of the sensing signals are different
due to the different bit rates of the input signals, and the difference between the pulse numbers is
proportional to the difference between the bit rates.

Therefore, a bit rate can be detected by checking the number of pulses of a sensing signal
generated for a predetermined time. However, such a circuit as can directly count the pulses of the
sensing signal to detect the bit rate of the input signal is difficult to configure since the current
optical transmission system employs a maximum bit rate in Gbps units.

Sub B6 To overcome this limitation, the bit rate deriving unit 40b low-pass-filters the sensing signal
and detects the bit rate from the resulting voltage level. Returning to FIG. 3, the bit rate deriving
unit 40b includes a filter 44 for low-pass filtering a sensing signal received from the operator 43 of

1 the identification signal generator 40a, an analog-to-digital converter (ADC) 45 for converting an
2 analog signal received from the filter 44 to a digital signal, and a determiner 46 for determining the
3 bit rate from the output of the analog-to-digital converter 45.

4 The filter 44 shown in FIG. 3 is a low pass filter. The filter 44 receives a high frequency
5 digital signal and outputs direct voltage components having levels according to the pulses of the
6 inputted digital signal. That is, the signal outputted from the filter 44 can be regarded as an analog
7 signal. The analog-to-digital converter 45 converts the direct voltage components into digital values
8 as a step prior to determining the direct voltage level of the inputted analog signal.

9 FIG. 5 is a graph showing the relationship between an optical signal bit rate and the output
10 level of the filter 44 shown in FIG. 3. In FIG. 5, the voltage levels of a sensing signal low-pass-
11 filtered in the filter 44 are shown with respect to bit rates ranging from 100 Mbps to 2.5 Gbps. As
12 shown in FIG. 5, since the voltage level increases linearly with the bit rate, the bit rate can be
13 determined from the voltage level.

14 By use of the bit rate identifying unit 50, the reference clock generator 60, and the clock and
15 data recovery circuit 70, the optical receiver of the present invention can detect a bit rate from an
16 optical signal at the bit rate received from an optical transmission system.

1 As described above, the bit-rate independent optical receiver of the present invention detects
2 a bit rate from an optical signal received at the bit rate in recovering the input signal. Therefore, it
3 can accommodate optical signals at different bit rates and recover data and a clock signal from an
4 input optical signal, thereby increasing transmission quality and a transmission distance.

5 Furthermore, the optical receiver can operate adaptively to a bit rate. Especially, when the
6 optical receiver is applied to a wavelength division multiplexing transmission system together with
7 other devices operated at different bit rates, there is no need for changing a channel card in the
optical receiver even if wavelengths assigned to the devices or a system structure should be changed.

8 While the present invention has been illustrated by the description of embodiments thereof,
9 and while the embodiments have been described in considerable detail, it is not the intention of the
10 applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional
11 advantages and modifications will readily appear to those skilled in the art. Therefore, the invention
12 in its broader aspects is not limited to the specific details, representative apparatus and method, and
13 illustrative examples shown and described. Accordingly, departures may be made from such details
14 without departing from the spirit or scope of the applicant's general inventive concept.